Space Tourism & Colonization

by Patrick H. Stakem

2017

Number 6 in the Space series.

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Introduction

This book covers the topic of Tourists trips to Space, which are not that far away, and some have already happened. Space travel is no longer the exclusive privilege of nation-states, and trained crew. For a while now, it has been open to health adventurers with lots of money. As more facilities are built to address the demand, less expensive options will become available. Space will never be perfectly sate, but it will always be an exotic location.

In 2004, the first privately built and operated vehicle to achieve human spaceflight, SpaceShipOne, made three flights to a sub-orbital altitude. This will eventually drive down the cost of accessing space for tourists. There are no technical issues, only financing and business operations to be defined.

Author

Mr. Patrick H. Stakem has been fascinated by the space program since the Vanguard launches in 1957. He received a Bachelors degree in Electrical Engineering from Carnegie-Mellon University, and Masters Degrees in Physics and Computer Science from the Johns Hopkins University. At Carnegie, he worked with a group of undergraduate students to re-assemble, modify, and operate a surplus missile guidance computer, which was later donated to the Smithsonian. He was brought up in the mainframe era, and was taught to never trust a computer you could lift. In addition, his father and mother were in the hospitality business, his father as the Manager of a Hotel. In grade school, when assigned the task of drawing a picture of his house, he was the last to finish, with 100 windows.

He began his career in Aerospace with Fairchild Industries on the ATS-6 (Applications Technology Satellite-6) program, a communication satellite that developed much of the technology for the TDRSS (Tracking and Data Relay Satellite System). He followed the ATS-6 Program through its operational phase, and

worked on other projects at NASA's Goddard Space Flight Center including the Hubble Space Telescope, the International Ultraviolet Explorer (IUE), the Solar Maximum Mission (SMM), some of the Landsat missions, and Shuttle. He was posted to NASA's Jet Propulsion Laboratory for Mars-Jupiter-Saturn (MJS-77), which later became the *Voyager* mission, and is still operating and returning data from outside the solar system at this writing. He initiated and lead the international Flight Linux Project for NASA's Earth Sciences Technology Office. He is the recipient of the Shuttle Program Manager's Commendation Award, and has completed 42 NASA Certification courses. He has two NASA Group Achievement Awards, and the Apollo-Soyuz Test Program Award.

Mr. Stakem has been affiliated with the Whiting School of Engineering of the Johns Hopkins University since 2007 He supported the Summer Engineering Bootcamp Projects at Goddard Space Flight Center for 2 years.

Where can we go, what can we see, are we there yet?

The *Fédération Aéronautique Internationale* defines space as beginning at 100 km altitude. Two of the 199 X-15 flights managed to reach that altitude, so the pilots were officially astronauts. So far, 3 nations have launched some of their citizens into space, with the former Soviet Union being the first. The United States followed along, and, more recently, China has sent some of their citizens to orbit. There have been spacefarers from over 40 countries, taken along on shared missions by the craft of the major space-faring nations. The International Space Station is truly an International effort, with crews from many nations represented.

This is not a technology challenge. You can do most of this now, with the right amount of money. As they say in the tourism and hospitality industry, tourist dollars do not need justification by the

bean counters. Tourism destinations do not need economic justification. Tourism is for recreational or leisure purposes. Make it available, and they will come.

Another option open to you might be a “pay-to-join” expedition. There's never enough penniless grad students, so volunteer to participate in a scientific expedition. They'll probably feed and shelter you, getting their payback from in-site work.

In 2004, President Bush signed into law the Commercial Space Launch Amendments Act, a law that allows commercial space tourism to proceed. In the US, The Federal Aviation Administration enforces this law. This is in line with the United Nations Outer Space Treaty of 1967, ratified by 102 countries. It makes countries responsible for the space activities of their citizens. The International Moon Treaty came into effect in 1984, and forbids private ownership of space resources or objects. Fifteen states have ratified this treaty. There will be loopholes exploited, and nations can withdraw from the Outer Space Treaty with one years' notice.

Steps in Space tourism

These are the near-time goals we can define for tourism in space. The first four have been done by humans. The first three have been done by tourists. A Habitat module is currently attached to the ISS for long term test in the space environment. For option 4, you can go with Space Adventures fore $100 million, or Russia will throw in a 2 week stay on the ISS as frosting on the cake. At the moment, these flights are suspended, due to the lack of capsules for ISS crew exchange.

1. Suborbital flight, to beyond the Kaman line, where you officially become an astronaut.
2. Visit low Earth orbit, on a short duration flight. (up & back)
3. Visit the ISS for a week.
4. Loop the moon.

5. Lunar surface visit.
6. Orbiting Hotel and recreational facilities.
7. Lunar Hotel and recreational facilities.
8. Martian outpost.

Approaches

1. Pay some serious money and enjoy the trip – a lot like a cruise, but much more expensive.
2. Pay some money to join a scientific expedition as a participant. This is done for archaeological 'digs" on Earth today.
3. Tag alone on a logistics run. You still pay, but not as much. Think, cruise on a tramp steamer.

Economics

Tourism is not driven by economic needs; it is driven by affluence. You have some money to burn, and you want to go some place new and exciting. You want bragging rights that you've been there.

Adventure travel can take many forms, but has three main components, a physical activity, sometimes strenuous, a culture exchange, and a connection with nature. Think about the round-the-world trips, the cruises to the Greek Islands, the African Safari's, the visits to Machu Picu. No longer is adventure travel a perk of the rich, but the middle class forms most of the volume. What we are talking about in the book is, indeed, for the ultra rich. But so was air travel in the 1930's, or cross-country train travel in the 1870's. The rapid growth of the airline business was called the "Lindbergh Boom."

The adventure traveler wants to get out of familiar surroundings and his or her comfort zone. Maybe add in some culture shock, and a pinch of danger. Extreme tourism involves dangerous locations or events. Space travel fits into that category at the moment. Some day, it will be as routine as air travel is today.

Tourism is the business of attracting, accommodating, and entertaining tourists. Tourism is a source of revenue for the entrepreneur, and a source of jobs for the skilled trades needed in the hospitality business. In travel, as in real estate, it's "location, location, location."

The Space Tourism Society is a 501(c) 3 non-profit, organized in the united States, with chapters in seven other countrys. It is focused on the emerging space tourism industry.

Space Tourists, so far.

There have been, to this point, 7 civilian space tourists, who have paid their way into orbit. These were conducted by Space Adventures. The Russians halted civilian flights in 2010. If you're getting paid to do it, you're an astronaut. If you pay to do it, you're a tourist.

- Dennis Tito was the first Space Tourist. He paid his own way to visit the ISS in 2001 on a Russian Soyuz craft.
- Mark Shuttleworth was second.
- Gregory Olsen went to the ISS.
- Anousheh Ansari was fourth, flying in a Soyuz capsule.
- Charles Simonyi flew in a Soyuz. He had so much fun, he went a second time.
- Guy Laliberté, a Canadian, flew in a Soyuz.
- Yi-So-yeon, a Korean, went to the ISS.
- Christa McAuliffe, Teacher in space, was killed in the Challenger disaster.
- Helen Sharman, first Briton in space, went via Soyuz to the Mir space station.

Spaceflight participants – these flew to orbit, but were not professional astronauts.

- U. S. Congressman Bill Nelson flew on the Shuttle Columbia in 1986.

- Jake Garn, of the Senate Appropriations Committee, flew as a payload specialist in Shuttle Discovery in 1985.
- Japanese TV reporter Toyohiro Akiyama flew to MIR in 1990. It was considered a business trip.
- Dr. Sheikh Muszaphar Shukor Al Masrie bin Sheikh Mustapha of Malaysia, orthopedic surgeon, went to the ISS via a Soyuz, and, no, it was not a house call. This was part of a program where Malaysia agreed to purchase Russian fighter jets in exchange for the ride.
- Richard Garriott, son of Astronaut Owen Garriott paid his way to the ISS, becoming the first 2nd generation space fairer.

NASA's input

This section discusses commercial efforts in the Space tourism area. As an example of some good lessons learned from NASA, let's take a look at Skylab. Keep in mind, NASA is not a tourist operation. Their focus is on exploration and science. While they may tolerate tourists to a certain extend, they tend to get in the way of the mission. Although recently, NASA said they would open the ISS to tourism, as soon as the U. S. had a crewed vehicle for transportation. NASA is a Federal bureaucracy, funded by the taxpayer. NASA Headquarters, in downtown Washington, way too close to both the White House, and the Congress.

After the Apollo program, with some spare Saturn rockets sitting around, the next big project was the Skylab space station (1973-79). This used a Saturn S-IVB upper stage as the structure for the station, launched by a Saturn-V with live first and second stages. The hydrogen fuel tank was re-purposed into the crewed facility. The payload to orbit was 170,000 pounds. The station was 82 feet long, 56 feet wide, and 36 feet in the other direction. It was quite visible from Earth, when the solar arrays caught the glint of the Sun. Astronauts were carried to the facility in-orbit on three missions in 1973-1974 by Apollo Command and Service modules launched on Saturn-Ib vehicles.

The Industrial design for the Skylab interior was headed by famed architect Raymond Lowey. He emphasized habitability and comfort for the astronaut, He included a wardroom space for meals and relaxation. He also wanted a window to view Earth and space. This has proved to be a great feature on the current ISS. Astronauts who participated in Skylab planning were dubious about the designers' focus on areas such as color schemes and decoration. They vetoed an entertainment center. Skylab food was improved over the earlier lunar mission food. Skylab missions were longer than previous capsule missions. The first mission was for 28 days, the second 59 days, and the third, 84 days in orbit. Each day had 90 minutes of exercise, to offset the effects of zero-G.

Each astronaut had a private sleeping area the size of a small walk-in closet, with a curtain, sleeping bag, and locker. Designers included a shower and a toilet. There was enough water capacity for one shower per person per week.

The station offered what a later study called "a highly satisfactory living and working environment for crews", with enough room for personal privacy.

All of NASA's data and designs are in the public domain. There are vast treasure-troves of information available from NASA online. Companies can enter a “Space Act Agreement” with NASA for the use of technology. The key point is, you don't need to be a “rocket scientist” to build an orbiting vacation center. The technology and the operational data is there, for free. You need a few dollars. Ok, a lot of dollars.

To date there has been a few civilian tourists who paid to go to the ISS. That market is going to open up with a new announcement by NASA's Chief Financial Officer in June of 2019. Perhaps as early as 2020, with new commercial options for transportation to the station, NASA will allow some tourist traffic. The stay time can be up to 30 days, and 4 persons can be carried.

Transportation costs will be around $60 million. Once you get there, your sleeping quarters will cost $35,000. per night, and you have to velcro your sleeping bag onto the wall. Hopefully, you will have paid attention on the operation of the toilet in the Russian module. There were talking about $50 per gigabyte to use their “wifi” to message Earth. Up to four can be carried. You can get your frequent flier points from Space-X or Boeing, who are introducing new capsules to remove the reliance on the venerable Soyuz. Brokers Bigelow Aerospace and Axiom Space have each reserved 4 launches. In addition, one space station port will be made available for commercial scientific equipment.

It gets complicated, because NASA is not the sole owner of the ISS. There are a variety of co-owners including Russia, Canada, and Japan. They could also develop tourism offers. And, as the ISS begins to reach end-of-life, and NASA and other agencies focusing on the Moon and Mars, the ISS facility might be sold to a commercial outfit. (Fixer-upper, good location, as-is, where-is, good views.)

Any rocket company providing transportation services to orbit must get a license from the Federal Aviation Administration, Office of Commercial Space Transportation.

Commercial Spaceflight Federation

The Commercial Spaceflight Federation is a Washington, D. C. non-profit trade organization, founded in 2006. It now has over 70 member companies, a who's who in the commercial space arena.. It serves as an advocate for access to space for not just scientists, but the general public. They address such issues as export control of technology, funding, regulatory issues, and standards. They serve as an industry point of contact on emerging topics such as Space Commerce, tourism, and issues related to spaceports.

Space Adventures, Ltd

To this writing, Space Adventures is the only private company that has sent paying customers to space. They work with NASA, the Russian Space Agency, and other private space companies. It was founded in 1998, and has offices in Tyson's Corner, Virginia. The company is made of of entrepreneurs from the adventure travel, entertainment, and aerospace industries.

They have sent multiple clients to the ISS, and were the company that booked Dennis Tito, the first space tourist. They did the same fro Mark Shuttleworth, Greg Olsen, Anousheh Ansari, Charles Simonyi (flew twice), Richard Garriott, and Guy Laliberte, the founder of Cirque du Soleil.

An option on their ISS visit is a spacewalk, for an additional $15 million.

They will be offering a Moon-direct option, without stopping at the ISS. They will not land on the surface, but will include a low-level flyover and a loop-around. This is expected to cost $100 million. Russia will do the same, and throw in a 2-week stay at the ISS, for $150-200 million.

On the low end, you could go with a sub-orbital flight, provided by Armadillo Aerospace, that at least will get you to astronaut status, for around $100,000. This service is no longer be available as of 2013.

Bigelow Aerospace

Bigelow Aerospace is an American commercial space company, headquartered in Las Vegas, NV. It was founded in 1998, and focuses on inflatable modular units, carried to orbit. The company licensed the technology from NASA, and has Space Act

agreements with the Agency in place. The company has enhanced the technology of NASA's TransHab module.

Several modules have been sent to orbit, including Genesis-I (2006) and Genesis-II (2007). Both remain in orbit but are retired. Both have an expected life of 12 years in orbit, at which point they will reenter the atmosphere and burn. Both Genesis modules were heavily instrumented. Questions remain about their longevity and safety in the space environment.

The Bigelow Expandable Activity Module (BEAM) is also in orbit, attached to the ISS. It was funded by NASA, and was launched on a SpaceX cargo mission. The emphasis of the inflatable modules is proving the radiation protection and debris shielding. It was launched in 2016, and evaluated through 2018. It is still attached to the ISS.

Bigelow hopes to put one of their Expandable Bigelow Advanced Station Enhancement (XBASE) modules on the moon by 2021. This is referred to as the B330 Module. Space Complex Alpha is their next-generation commercial space station. He has launch agreements in place with SpaceX and Lockheed Martin, and has launched on the Russian Dneiper vehicle.

Bigelow himself came out of the hospitality industry, and hopes to set up space hotels and habitats to encourage space tourism. One of these was the 2005 concept, CSS (Commercial Space Station) *Skywalker*. He is also addressing manufacturing in space, and has said he has agreements in place with six nations to pursue this.

His other concepts include the Next-Generation Commercial Space Station, and Space complex Alpha, consisting of dual Sundancer Modules and a BA330. The BA330 *Nautilus* module has an enclosed volume of 330 cubic meters. The Sundancer would have had a volume of 180 cubic meters, but the project was canceled. The constraining factor at the moment is the lack of crew transportation systems, consisting,only of the Soviet Soyuz. The U.

S. has no current crew transportation for space, since the Shuttle fleet as been retired.

In 2013, Bigelow signed a contract with NASA, exploring private ventures contributing to space exploration, and focusing on lunar base. The FAA's office of Commercial Space Transportation reviewed Bigelow's lunar plans.

XCOR Aerospace

XCOR is involved in private spaceflight. They developed their own engines, based on early work at another start-up, Rotary Rocket Company. Located at the Mojave Air and Space Port, they put their own rocket into a vehicle manufactured for them by Scaled Composites, who happen to be at the same facility. Their unique approach allowed for returning and safely landing the booster, rather than throwing it away after one use. The prototype was successfully flown three times, before the company ran out of money.

XCOR designed, built, and flight-tested their EZ-Rocket in 2001. Their manufacturing facility is in Texas. They joined with United Launch Alliance in development of a LH2/LOX upper stage engine. This was test-fired in 2011.

XCOR Science offers payload flight for educational and research organizations. The maximum payload for the crewed Lynx-1 and -2 is 140kg. There are actually two cargo areas, the first having a capacity of 20 kg, behind the pilot. The other space is created when the second seat is removed.

EZ-Rocket was a Rutan Long-EZ aircraft, fitted with two rocket engines in place of the propeller units. It was said to be “the first rocket powered aircraft built and flown by a non-government entity.” Evidently, they didn't do their homework, about the German work in the 1930's leading to the adoption of the rocket engine for fighters. The EZ-Rocket, piloted by Rutan, carried some

U. S. Mail. Another project was the Rocket Racer, designed for the Rocket Racing League. This was a group that develops and flys rocket powered aircraft in a closed circuit air-racetrack. It was founded in 2005, with first flights in 2010.There were six racing teams. It sounds exciting, but financing was not forthcoming, and the league is now defunct. It was referred to as *Nascar with rockets*.

XCOR offered suborbital rides with their Lynx models. They purchased Space Expedition Corp., and are using them as their marketing group for suborbital flights, out of the Mojave Spaceport. XCOR filed for Chapter 7 bankruptcy, and closed their doors. They filed for bankruptcy in 2017. It is unclear where it's intellectual property will wind up.

Space Expedition Corporation

The Space Expedition Company (SXC) was founded in 2008. It did not want to spend money to develop its own rocket, so it arranged to lease one from XCOR. SXC was acquired by XCOR in 2014. The company was renamed XCOR Space Expeditions. It offers suborbital flights from Mojave in Arizona, and California. They were planning on a spaceport facility on the Caribbean island of Curaçao.

The Orbital Mission Explorers Circle is a program that lets interested individuals reserve seats on future flights. Sergey Brin, of Google, was a founding member. A reservation is $5 million. The Circle is a fraternity (and sorority) of future private space explorers. Founding Explorers, of which there are six positions, have priority access.

Another announced program will offer a spacewalk option. It would allow about 1.5 hours outside the ISS. More training is required for this option.

Thinking big, there is also a lunar option, This is estimated to cost $100 million per seat, but provides a circumnavigation of Earth's first satellite. This would use a Soyuz capsule, which will dock in orbit with a service/propulsion module (like Apollo did), This would be about a 10-day mission.

The obvious next step is a lunar drive-by, or landing.

Virgin Galactic

Virgin Galactic is providing suborbital flights, and plans to support space tourism as well as science missions. The company is owned by Sir Richard Branson. It was the first privately built and operated vehicle to achieved crewed spaceflight. This was on the 100th anniversary of the Wright Brother's flight, From airplanes to space plans to orbit in 100 years. Let's keep that up. No, let's go faster.

Scaled Composites, owned by Virgin Galactic, developed a air-launched vehicle, for access to space for tourists. The carrier vehicle, White Knight Two, carries the smaller SpaceShipTwo to a high altitude,. At this point the two vehicles separate, and the White Knight flys back to a runway landing as the smaller craft continues to orbit with its rocket engine. The two vehicles were designed and built by aviation and space pioneer Burt Rutan. The plan is to have five SpaceShip-2's, the orbital vehicle, and two WhiteKnight-2's, the crewed carrier vehicle. Two SpaceShip-2's are under construction, and there is currently one White Knight-2, the carrier ship.

The White Knight, sometimes called a Flying Space Aircraft Carrier, has a crew of two. It's cargo capacity is 37,000 lbs to 50,000 feet. If it carries an “upper stage”, the Launcher-one, it can put 200 kilograms to low Earth Orbit. White Knight has four Pratt & Whitney turbofan engines. The wingspan is 41 feet, and there are dual fuselages. The second fuselage can hold additional crew members, or tourists. It glides back to a landing at Spaceport

America in the Mojave Desert.

Unfortunately, the first SpaceShipTwo broke up during a test flight, killing one pilot, and injuring the other, although he parachuted to the ground. Before the accident, the vehicle did indeed reach “space.” The second unit is undergoing flight testing at this writing. It operates from the Mojave Spaceport, and will offer suborbital flights. It is about ready to return to flight as of this writing, with Sir Richard himself reserving a slot.

Benson Space Company

The Benson Space Company, founded by Jim Benson, was organized in 2006. It was seeking to use the SpaceDev Dreamchaser vehicle Unfortunately, Benson passed away in 2008. He was the founder of SpaceDev. The company was acquired by Sierra Nevada Corp.

Blue Origin

"...to build space hotels, amusement parks and colonies for 2 million or 3 million people who would be in orbit. 'The whole idea is to preserve the earth' he told the newspaper .... The goal was to be able to evacuate humans. The planet would become a park." Jeff Bezos, High School Class valedictorian, 1982, Miami Herald.

Blue Origin is a spaceflight services company founded by Jeff Bezos, of Amazon. The company “is developing technologies to enable private human access to space with the goal to dramatically lower costs and increase reliability.” They are focusing on vertical take-off, vertical landing reusable vehicles. The name refers to Earth. Their spacecraft is named *New Shepard,* and has been flown un-crewed as of this writing. It went almost to space, reaching just shy of 100 km. The second flight did go beyond 100 km, and both the capsule and booster were recovered. Crewed flight will happen sometime in 2018. The company uses its own launch vehicles. The

company is located in Washington State, and uses a launch facility in west Texas for sub-orbital launches. They have leased facilities at the Kennedy Space Center for orbital launches. Some technology from the earlier McDonald Douglas-NASA DC-X project influenced the Blue Origin.

The orbital rocket is named "*New Glenn*" after Astronaut John Glenn, The first stage will have seven of their BE-4 engines, and will be recoverable and reusable. The BE-4 engine production facility is in Huntsville, AL. The rocket portion was recovered and reused a total of three times.

The Crew capsule of the New Shepard will hold three or more astronauts, and has been launched, un-crewed, to space, by the definition of 100 km.

The company has a NASA Space Act Agreement in place under the Commercial Crew Development Program. They also will offer trips to space, and "let the demand for space tourism determine how many additional vehicles will be needed." This is referring to their New Shepard launch vehicle. The crew capsule can carry six. Currently, commercial sub-orbital flights are scheduled for 2019. This will exceed the Kaman line. So far, they have had eleven flights.

Axion Space

Axion, of Houston, envisions a commercial replacement for the ISS. This will be used for research, manufacturing, and space tourism as early as 2020. Before their station is ready, they plan to deliver tourists to the ISS, on a non-interference basis to the station's mission. Their modular station will be built in an incremental manner. As the ISS is decommissioned, the Axiom modules will be separated, and go their own way. At this point, they will focus on tourism and in-space manufacturing as money-makers.

At this writing, they say their commercial flights to the ISS have not started.

Space-X

Space-X has an impressive track record, including the first privately funded liquid rocket engine to orbit, the first to launch and recover a rocket, the first private company to send a vehicle to the ISS, and the first reuse of an orbital rocket. Their Dragon capsule is designed in two versions, to take personnel and supplies to the ISS. The cargo version has been in operation since 2010. The crewed version is scheduled to be tested in 2019 as of this writing. After the newer version is declared operational, the old version will still be used for cargo flights. This will provide a human-rated transportation option to the ISS, besides Soyuz.

Their newer Dragon V2 capsule has a capacity of 7 crew. The Dragon capsules have an integral launch escape system, consisting of rocket engines. The vehicles are capable of autonomous rendezvous and docking. The onboard control is a tablet computer. They can parachute to a water landing, or do a dry landing, assisted by the external rocket motors. The capsule is partially re-usable, with a projected life of ten flights before refurbishment.

At a NASA news conference in 18 May 2012, SpaceX confirmed again that their target launch price for crewed Dragon flights is $160,000,000, or $20,000,000 per seat if the maximum crew of 7 is aboard, and if NASA orders at least four DragonRider flights per year. This contrasts with the 2014 Soyuz launch price of $76,000,000 per seat for NASA astronauts going to the ISS.

Space-X hopes to send their privately crewed Dragon spacecraft around the moon, by 2022. This would carry two tourists. Space-X has been accepting deposits for this activity.

SpaceX has said it views space tourism as "an important step toward enabling access for everyday people who dream of traveling to space." Japanese billionaire Yusaku Maezawa will be SpaceX's first space tourist. He has a ticket for a slingshot trip around the Moon as early as 2023. He's planning to take six to eight artists with him on the mission free of charge.

"I want to share this experience and things with as many people as possible," Maezawa said at a news conference. "So, I choose to go to the Moon with artists."

Musk is currently saying the company no longer has plans to certify the Falcon Heavy for human spaceflight.

Sierra Nevada's Dream chaser

This craft is a 7-crew Earth orbital space plane, developed with $20 million of NASA seed money. The Dream Chaser was based on the circa-1990 NASA HL-20 Personal Launch System, a mini Space Shuttle designed as a lifting body. NASA-Langley, the lead center for the project, had not gotten to the implementation stage. The unit would have limited cargo capacity, but could get crews to and from orbit, particularly the ISS.

Sierra Nevada did not make the final cut in the competition for commercial transportation services to the ISS, losing to SpaceX and Boeing This was supposedly due to lack of technology maturity. Sierra Nevada decided to pursue the Dream Chaser project independently.

Sierra Nevada did win a Commercial Resupply Services contract from NASA, for a minimum of six launches. These missions will use the Atlas V launch vehicle. First cargo flights to the ISS are envisioned in 2019.

Sierra Nevada also supplied the rocket motors for Virgin Galactic Spaceship Two, and for Scaled Composites.

Playboy Enterprises

Playboy has proposed an orbital "space club", in conjunction with Virgin Galactic. Their plans include a restaurant and a zero gravity dance club. This was discussed in the March, 2012 issue of their magazine. The concept is a ferris-wheel shape, like the original Von Braun Space Station.

There are using a cruise ship model, with bar, restaurant, dance club, casino, and waitresses in jetpacks. An arrangement is in place with Virgin Galactic to use their SpaceShipTwo, for around $200,000 for transportation,

Is this real, or just a publicity stunt? Well, there is nothing in the laws of physics to prevent it – it will only take money. I wonder about the effects of alcohol in Zero-G?

Excalibur Almaz

Excalibur Almaz is an ambitious private space flight company planning not just Earth orbit, but lunar and deep space services. It is cooperating with XCOR Aerospace. The company is located on the Isle of Man. It has a Space Act Agreement with NASA in the commercial Crew Development area. They purchased the hulls surplus capsules from the Russian Almaz military space station program, updated with more modern electronics. The plan is to launch this station into space, and have it visited by researchers and space tourists. It remains to be seen whether this plan will continue.

There is also an option being discusses to take three tourists on a flyby around the moon, using Almaz space station modules. This was to be a 6-month mission, but the concept seems to have been abandoned.

Stratolaunch Systems

This space start-up combines Paul Allen, of Microsoft, with Burt Rutan of Scaled Composites. The project involves a carrier aircraft and a multistage air-launched launch vehicle. First flight was expected in 2019. The founder passed away in October of 2018, and the company ceased operations,

MirCorp

MirCorp was a circa 1999 commercial space company exploiting the Russian Mir Space Station. It accomplished the first privately funded expedition to a space station, the first privately funded cargo resupply mission, the first privately funded spacewalk, and the first flight of a space tourist. A coup was getting the NBC Network to produce a reality show, “Destination Mir.” The company also advertised via Youtube.

MirCorp fashioned its business model after that of airlines. Airlines don't built the planes, but rather buy or lease them. They provide a money-making service using the planes to move tourists around.

Opposition by the U.S. caused MirCorp to fail, but not before it showed a way to make money in the space tourism business, ironically, by the Russians.

dearMoon Project

This is a private lunar tourism project, funded by a Japanese Billionaire. Yusaku Maezawa and several artists will make the six-day journey on Space-X's BFR Spacecraft. That system is under development and test at the moment, for a possible flight in 2023.

Asgardia, another approach

The Space Kingdom of Asgardia is a proposed space-based nation-state, announced in 2016, by Igor Ashurbeyl. The Outer Space Treaty currently governs all extra-terrestrial activities by governments, NGO's and commercial entities. The treaty was put in place in 1967. As of July 2017, 107 countries are signatories, with 23 signed, but not finished ratification. The treaty is an attempt to define a legal framework for Space Law, as was done for the Law of the Sea previously. No government can claim a moon or a planet for its sole use. Space objects that are launched by signatories remain the property of the launch entity. Accordingly, the owner is responsible for damages caused by that object. The government is responsible for the activities of NGO's under their jurisdiction.

Anyone can apply for Asgardia citizen, and more than ½ million have. The entity wishes to apply for U.N. Membership, although it has no terrestrial territory. It has launched a Cubesat to the ISS. The project is currently privately funded, but will seek crowdfunding. They wish to have their own in-orbit colony,

Vehicles

What are our choice of vehicles to get to space? For getting to orbit, it is fairly restricted at the moment. The Russian Soyuz-MS is your only choice, at the moment, to get to the ISS. The craft is in it's fourth generation, and holds three. Occasionally, only two “professionals” need to travel, so there is a seat available. It will cost you $76 million.

The Space-X Dragon capsule is used for uncrewed resupply of the ISS at the moment. The upcoming Dragon-2 will be capable of flying 7 persons. It will have a projected cost per seat of $20 million, which is projected to decrease, since the launch vehicle is recoverable and reusable. Similarly the Boeing CST-100 will be available, with a crew capacity of 7. It is intended to be reusable,

up to 10 times. The agreement with NASA allows Boeing to sell seats to Tourists, competitive with the cost of Roscosmos seats.

One interesting spin-off of the development of winged craft that reach orbit, then return to a runway, is the concept of very fast air travel. Here, the plane is taken up on a mothership, or launched vertically on a rocket. It follows a trajectory hat allows it to reach anywhere on the planet in 10's of minutes. This was an offshoot of German World War-II research on the “Antipodal Bomber” by Sanger.

Training

Space is a strange environment, and the savvy traveler has to understand and overcome its quirks. perhaps the greatest of these is weightlessness.

NASA introduced its Reduced Gravity Research Program, using aircraft to fly parabolic trajectories for brief periods of weightlessness, The aircraft were named Weightless Wonders, but are most popularly known as Vomit Comets.

The parabolic flight path to produce short periods of zero-gravity was proposed by German aerospace engineers and physicists brought to the U.S. after World War-II. The aircraft initially fly's at an upward pitch angle of 45 degrees. When power is reduced, and the nose is let down, the aircraft is in a ballistic trajectory. Then the maneuver is repeated. You get about 25 seconds of weightlessness for every 65 seconds. The other 40 seconds are at 2G's. Many other countries have such aircraft as well. In addition to human passengers, animals have been flown to see their behavior in Zero-G, notably birds, and cats (on separate flights). NASA now uses the services of Aero Gravity Corporation's modified Boeing 727-200.

Two other companies in the U.S. Offer similar services, Integrated Spaceflight Services using Airbus A340's and Aurora Aerospace using a Rockwell Commander aircraft.

You can schedule a commercial zero-gravity flight right now with Zero Gravity Corporation of Dulles Airport in Virginia. It is $4950. That corporation, which holds the first and only FAA-approved provider of weightless flights to the general public, was acquired by Space Adventures in 2008.

According to aviation experts, roughly one-third of passengers become “violently ill.” Another third are not affected, and the remaining third have only slight effects.

The aircraft feature easy-to-hose-out plastic cabins.

Destinations

This section describes the expeditions, in increasing order of cost, that the space tourist can take today, and will be able to take soon.

The Kaman line

The Kaman line is is at an altitude of 100 km, the “official” beginning of space. The X-15 rocket plane was the first to reach this altitude, making the pilot, Joseph A. Walker, an official Astronaut, in 1967.

SpaceShipOne was designed to win the Ansari X-Prize, for the first private manned spaceship. In 2004, SS1 made 3 crewed suborbital flights into space (above Kaman line), being the first privately built and operated craft to do so. The craft went on to win the X-Prize in 2004.

ISS

Our orbital destinations are similarly limited at the moment. Unless we are just going to Space to say we did it, our short term destination will be the ISS.

In 1993, United State's Space Station Freedom Project, to create

the International Space Station kicked off. On-orbit construction began in 1998, and was completed with a last Shuttle mission in 2011. It is the largest artificial satellite in Earth orbit, and can be seen from the ground with the naked eye. The ISS is a synthesis of several space station modules from the U. S., the Soviets/Russians, the Europeans, and the Japanese. It serves as a laboratory, observatory, and factory in Earth orbit, and is continuously crewed. Part of its mission is to collect information on items in orbit for long duration. It is currently funded through 2024. The assembly began in 1998, with the first module being the Zarya, It now has 15 pressurized modules. Five more are planned,. This is the advantage of a modular architecture. It is the 11th station sent to orbit. Early stations such as Skylab were not intended for resupply.

The International Space Station is continuously crewed, and orbits the Earth at an altitude of some 250 miles. It is quick, traveling at 17,300 miles per hour. It is also expensive, representing an investment of some $100+ billion dollars by the world community, mostly by the United States and Russia. It is thus the most expensive object ever constructed by mankind. It has been visited by astronauts and cosmonauts from some 15 nations, and by paying tourists. It can generally be found at an altitude between 300 and 435 km, and can be seen by the naked eye in the daytime, if you know here to look (there's a NASA ap for that). It has been continuously occupied for 16 years, as of this writing and visited by travelers from 17 nations, some for work, some for tourism. It normally has a crew of 6, and masses 419,500 kg, the largest item in orbit.

Currently, the operational crew of the ISS is limited to the number of seats in the return craft attached to the station; think, lifeboats. After a period of several private paying customers, NASA has been reluctant to allow more “civilians” to visit, claiming it takes away from the scientific mission. But they concept has changed, now that two options (Boeing and Space-X) are about ready to provide crewed flights. The Boeing CST-100 Starliner capsule will be making a manned flight to the ISS soon, as will Space-X's Dragon.

The Bigelow Expandable Activity Module (BEAM) is a privately owned, inflatable habitat module, developed from NASA technology. It came to the station in 2016, and, so far, has remained inflated. Bigelow Aerospace hopes to use such modules in its own space habitat project. In more than a year in orbit, it has worked well. It is currently used as a storage area.

A start-up, Orion Span has a luxury orbital hotel in the works. A maximum of 6 guests can be accommodated, for up to 12 days. Current price is estimated to be $9.5 million.

At the moment, the only way to get humans to or from the ISS is the Ryussian Soyuz capsule.

Dangerous to get to, Dangerous to get back from, Easy Place to Die (describing the 1890's Klondike Gold Rush)

Becoming a Space Tourist

Is a Space Journey dangerous? Of course. So is a Cruise ship, and airplane ride, commuting in traffic, and biking around your neighborhood. In those areas, we have defined and controlled the risks. We accept those risks when we travel. Space travel has a relatively short history, and is inherently more risky than staying on Earth. On the other hand, 19th Century folk would be somewhat reluctant to fly on an airplane.

Once you have paid your deposit on the trip, and gotten a physical, the next step is probably a ride on the Vomit Comet. This affectionate name is applied to aircraft that fly a trajectory that alternates high-G with zero-G. Zero Gravity Corp, flying out of Dulles Airport near D.C. is currently the only company licensed by the FAA to do these flights.

There will be an orientation session, giving you information on the flight, the destination, what to expect, what to do and not do. Memorize this, there will be a quiz. Like learning where your

lifeboat is located on a cruise ship, if you need to know this, you REALY need to know.

Orbiting Hotels and Sports Centers

The dynamics of an artificial gravity swimming pool have been studied, and such a facility would provide a unique addition to an orbiting hotel. Variation of Earth-based sports will have 0-G equivalents, but a little gravity allows easier transition.

In zero G, if we had a pool module with an airlock, we would find the water, due to surface tension, formed a large sphere. There would be a lack of buoyancy, but normal swimming motions, in a reaction against the water, would still be effective. One issue is, you would not spontaneously float to the surface.

Further along, we could envision vacation destinations on the lunar surface. Here, we operate in about 1/6 of the gravity we are used to, and the water will stay in the designated pool. Where does the water come from? There is thought to be large amounts of water ice in craters at the lunar poles. This is being sought, because it can be converted to hydrogen and oxygen (rocket fuel) by solar electrolysis. We can just define the ”rocket fuel holding tank” as the swimming pool.

Besides defining variations of Earth-sport, we can implement a new one in Lunar gravity – flying. Since our weight will be 1/6, this is quite feasible with strap-on wings. It will take a bit of getting used to, but look forward to it at the Lunar Icarus Center.

Another activity that can evolve in lower-G / zero-G is performance art. Earth-developed scenarios could be modified for the Zero-G environment. To date, almost all space voyagers have been scientific/technical folks. As Space Tourism opens this to “ordinary people,” entirely new things will evolve, that we haven't thought of yet.

From NASA studies, after 2 days in weightlessness, the spine straightens out, and you grow about 3% in height. This is an issue

for space suits. Weightless posture is different. Adapting back to Earth-normal gravity takes a few days, as well.

Communications with the ground is no problem, either direct or through one of the Tracking and Data Relay Satellites. The orbiting facility can implement a cell phone hot spot and wifi. It will be expensive to use. So, what area code do we use for Earth orbit?

Should we take our pets with us? Cats have done well in adapting to Zero-G, from flights on the Vomit Comet. A concern for all manner of pets is waste disposal. If the cost of your pet's flight is about the same as yours, Little fluffy will probably remain on the ground.

Solar flares, Coronal Mass Ejections can also endanger the crew and guests. They then have to gather in their equivalent of a tornado shelter. A series of sentinel satellites track these events originating in the Sun, and provide ample warning time. To date, no evacuation of the International Space Station has been necessary. The Crew normally is exposed to the same radiation in 1 day, which a person one Earth would get in a year. This should not be an issue for short-stay guests, but could limit the working duration of staff.

Staff will need training beyond what the tourists get, because they will be living in the facility, and will, like ships' stewards, be responsible for safety. There are also the issues of business insurance, and safety certification. As with any totally new adventure, some of this will initially be solved with guesswork.

A Russian Company, Orbital Technologies, was planning for a luxury hotel in orbit in 2010, as a destination. Why not a luxury facility? Would you pay a million for a trip to a Motel-6 in orbit? The facility will have seven guest rooms, and is projected to be at an orbit of 220 miles. First launch was to be in 2016, but that never happened. Status of the project is unknown.

The Spanish Company, Galactic Suite Design, is developing concepts for the interior of space habitats. They had a project in

2007 to design an orbiting station.

Keep in mind, every object put into Earth orbit needs a DE-orbit plan, to prevent reentry of large objects that could do damage on the ground. Also, large orbiting bodies need periodic reboosts, to keep the orbit from decaying.

The Moon

The next logical step beyond Earth orbit is the Moon, as a destination. There are several options, with varying complexity.

Lunar loop

The lunar loop is a trip around the moon, without landing. Space Adventures has a planned mission, DOSE-Alpha, that takes 2 tourists around the moon, within 100 km of the lunar surface in a Soyuz spacecraft. The crewed mission duration is a week.

Lunar orbit

This option avoids the landing/takeoff phase, and provides a period in lunar orbit, where the back side would be visible as well. This would include entering and exiting lunar orbit, as the Apollo mission did.

Lunar landing and outpost

NASA's Lunar Outpost on the surface is on hold, but they are pursuing the Deep Space Gateway with ROSCOSMOS. This will allow operation of telerobotic rovers on the surface.

One ideal structure for lunar bases (that the author has worked on) is lava tubes. These are found on the Earth as well, and the cooled lava provides a hard, sealed surface. It just needs to be capped with airlock doors, and no further exterior construction is required.

NASA is looking to private enterprise to provide logistics support for the lunar surface, and some companies are making lunar plans

themselves. Bigelow Aerospace has plans to build bases on the moon, based on their inflatable modules, originally developed from NASA technology.

Delivery company DSL and European aerospace company Airbus Defense and Space are working on a Lunar Delivery System. It won't be overnight, but it will cost you $1.2 million per kilogram. Airbus is interested in the *Peregrine* lunar lander, with a cargo capacity of up to 265 kilograms, developed by Astrobotic, a spin-off from Carnegie Mellon University in Pittsburgh. Astrobotic is already participating in NASA's CATALYST program, and says it has 10 payload delivery contracts in place. It is also a participant in the Lunar X-prize competition. DHL currently serves more than 220 countries, but only one planet. They plan to deliver to the lunar surface MoonBoxes, small boxes of about 1 inch in diameter, that will be left on the lunar surface.

The CATALYST (Lunar Cargo Transportation and Landing by Soft Touchdown) Project is a NASA initiative to develop robotic lunar landers to deliver payloads to the lunar surface. This will be done in partnership with U.S. commercial players. The project has already signed up three company's with Space Act Agreements. Letting the delivery service go commercial, NASA can focus on the science and technology.

NASA's Commercial Lunar Payload Services Program (CLPS) solicited proposals from a group of company's for delivery services to the moon. Significantly, these are all aerospace company's, not logistics companys such as Fedex and UPS. Astrobotics is partnered with logistics giant DHL. Some of thework is a spin-off of the Google Lunar X-prize efforts, which did not have a winner. Three companies have been selected, Masten Space Systems of Mojave, California, Astrobot Technology of Pittsburgh, and Moon Express, of Moffett Field, California. Moon Express holds the first commercial license from the U.S. Government to go to the Moon.

Amazon is addressing lunar delivery, as Jeff Bezos is head of Amazon as well as rocket company Blue Origin. Amazon knows a

lot about getting stuff delivered, quickly and efficiently, while controlling costs. We hesitate to refer to this as *Lunar Prime*. There is also a need for delivering material back from the moon to the Earth.

Other private company's involved include OffWorld; focusing on worker robots, and *ispace* in Japan.

ESA has plans for a lunar resort called the Moon Village. The infrastructure would be launched to the lunar surface and constructed by telerobotics. Besides tourism, the established base could support lunar surface research and manufacturing. The projected date for this project is 2030. It is projected that this facility will be at the lunar poles. Theme Parks, we need lunar theme parks.

New tourism markets develop slowly at first, but can accelerate as the word gets around. The tourism economy of Hawaii is an example. You have to find a new and exciting place (check!) that is convenient and affordable to visit. Affordable means different things to different people. A person might be willing to spend a lot for a one-time, bucket-list destination. As operations become more routine, cost savings can be implemented and assessed.

Mars Fly-by

In 2013, the Inspiration Mars Foundation, a non-profit founded by Dennis Tito, proposed a manned mission for a MARS fly-by for 2018. The details have been removed from the Website. This was estimated to require up to $2 billion ($10^9$) dollars. Space-X had been contacted as a possible vehicle provider. A “Plan-B” was defined using the known Venus-Mars flyby, for 2021 (when the planets were aligned properly).

There is also a one-way trip option proposed by several space enthusiasts. This option assumes you get it right the first time, and there are still a lot of unknowns. On the other hand, establishing a colony may be easier than the return journey. The current thinking

is to launch the habitats and required equipment before the crew. It is still a leap of faith.

Space Colonization

Enjoyed your trip, and your destination, and decided to move there? There's no options for that...at the moment. At the ISS, you can stay about a year, but then you reach your limit, due to radiation. In a lunar habitat, it would be buried in the ground, so you could stay longer.

Let's fast forward a few years where colonization is an option. We would need a colony that manufactures most of its needs onsite, and doesn't require frequent logistics flights. This means a local source of water and oxygen, and greenhouses for local food production. With local water ice, we can get oxygen (and hydrogen, for rocket fuel).

Consider the voyages of exploration from Europe to the “New World.” They had to find a source of water after a while, and something other than fish to eat. They may have needed timber for ships repair, but they brought along the right tools and skills. If we want plants and livestock on the moon, we'll have to bring them along. I don't know about large livestock, but chickens would have a blast – finally, they could fly.

Solar power would be the norm. That works out to about Jupiter's orbit, with the latest high efficiency solar cells.

A nuclear submarine can stay submerged for months, with limited communications, because that can give away its position. Crews have to be trained to operate efficiency in that environment of isolation. Similarly, outposts in Antarctica and drifting ice stations at the North Pole have similar problems, but with more open communications. The research stations in Antarctica are mostly shut down over the winter, with only a small maintenance crew. This has lead to a condition called “winter-over syndrome,” with a span of behavioral and medical issues. There is also a specific Polar T3 syndrome.

A specific program addressing the Mars issues is the Flashline Mars Arctic Research Station (FMARS). There is currently one such facility in the Arctic, with a second in the southern American desert. The first station is on Devon Island in the Arctic sea. It is located on a ridge, overlooking a large impact crater, about a thousand miles from the North Pole. The facility was built in 2000, and is operated by the Mars Society, a non-profit. It is used to define and refine field procedures, test habitat design, study crew performance, and selection criteria. It began operations in 2001. Generally, there is a core crew of ten, with visiting researchers and assistants. A hazard probably not found on Mars is the occasional polar bear, looking for a quick meal. One outside crew member is always armed. Communication to and from the station to external sources is delayed 20 minutes, to simulate the one-way radio/light travel time to Mars. The crew keeps to the somewhat longer Martian Sol day. A similar facility was planned for northern Iceland, but ran into money problems.

The Biosphere-2 project, located in the Arizona desert, supported 8 humans for a year in a closed ecosystem. It is rather large, covering more than 3 acres. It operated twice, in 1991-93, and in 1994. It was built the Space Biosphere Ventures in 1987-91. During its operational periods, much good data was compiled. It is now operated by the University of Arizona.

The ability to make spare parts on-site implies bring along the right tools, and using local materials. Three-D printing of parts on the ISS has been successful.

The moons of Jupiter could possibly provide habitable conditions, as well as a source of raw materials. Jupiter's moon Europa seems promising, and it is thought the moon has a sub-surface ocean under the ice crust. The moon Callisto is also a possibility, and it is further from Jupiter and its trapped radiation belts. Colonies at these distances from Earth would certainly need to be self-sufficient, due to the long travel time involved.

The next step beyond a remote, fixed colony is a colony ship, which would be on a long journey. Various approaches have been looked at, such as the generation ship, which is the home to multiple generations of space-farers, and the sleeper ship, which uses hibernation.

Design Studies for Colonies

People have been thinking about habitats in space for a long time. Hales book, “the Brick Moon,” in 1869 applied 1860's thinking and technology to the problem, and came up with a hand-waving launch process, but a viable construction – essentially heat-resistant tiles.

One hundred and twenty-eight Nations have signed the UN Treaty that states no country can “own” part of a celestial off-Earth body. It should be interesting to see how this plays out, after commercial entities begin to mine the moon and asteroids for profit.

The commercial company Blue Origin is actively developing a lunar lander. The company is owned by Jeff Bezos, who also owns Amazon, and the Washington Post. They are also developing their own heavy lift rocket, the New Glenn. Boeing is looking as a cis-lunar habitat. Lockheed Martin and United Launch Alliance are focusing on Mars.

Lower Cost Options

Generally, a flight for a human crew is more expensive that for cargo. Thus, if you want to fly into space, but are put off by the costs, consider this. Cleestis.com will fly your cremated remains to Earth orbit on what they call a memorial spaceflight. Their seventh flight is scheduled for the second quarter of 2018. The service is available for under $5,000, a real bargain. And, you get to contribute to the growing orbital debris problem.

After-words.

Ok, thanks for buying this book. I am trying to finance my lunar vacation. I am one book sale closer to my goal.

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Glossary of terms

AFB – Air Force base
Apogee – furthest point in the orbit from the Earth.
ASCE – American Society of Civil Engineers.
ASIN – Amazon Standard Inventory Number
BEAM – Bigelow Expandable Activity Module
Bean Counter – slang, accountant.
BEO – beyond Earth orbit.
BFR – (SpaceX) Big Falcon rocket.
Blooster – balloon-based launch vehicle
C3PO – NASA Commercial Crew and Cargo Program Office
CME – (solar) Coronal Mass Ejection
ConOps – concept of operations
CSF – Commercial Spaceflight Foundation
CSS – Chinese Space Station
CST – (U.S. Office of) Commercial Space Transportation.
C&W – caution and warning
Cyrogenic – pertaining to very low temperatures.
DRM – design reference mission.
ECLSS – Environmental Control & Life Support System.
EELV – Evolved Expendable Launch Vehicle (U. S.)
ESA – European Space Agency
ETR – Eastern Test Range, Cape Canaveral, FL
EVA – extra-vehicular activity
FAA – Federal Aviation Administration, oversees spaceflight as well.
GEO – geostationary orbit
GPS – global positioning system
GSFC – NASA Goddard Space Flight Center, Greenbelt, MD.
HITL – Human in the loop.
HSIR – human systems integration requirements.
IISL – international institute of space law.
ISBN – international standard book number.
ISS – International Space Station
JSC – Johnson Space Center, Houston, Texas.

Kármán line – international definition of the beginning of Space. 100 Km above the surface.
KSC – NASA Kennedy Space Center, launch site, Florida.
LEO – low Earth orbit
LSSPO – (NASA) Lunar Surface Systems Project Office, JSC.
MIR – Russian Space Station.
MPCV – multi Purpose Crew Vehicle
NASA - National Aeronautics and Space Administration.
NEO – near Earth object.
NGO – Non-governmental organization, commercial or non-profit.
NHV – net habitable volume
Orbitel – orbital hotel
NOAA – (U.S.) National Oceanographic and Atmospheric Administration.
Perigee – closest point in the orbit from the Earth.
PSF – Personal Spaceflight Federation
RF – radio frequency.
ROSCOSMOS – Russian Space Agency
RPOD – Rendezvous, Proximity Operations, Docking
SHFE – space human factors engineering
SI – System International – the metric system.
Soyuz – Soviet/Russian crewed capsule.
SXC – Space Expedition Corporation
SPACE Act, Spurring Private Aerospace Competitiveness and Entrepreneurship, 2015
STS – Space Transportation System (Shuttle)
SXC – Space Expedition Corporation.
TDRS – Tracking and Data Relay Satellites.
Terraforming – modifying the ambient environment tmo be Earth-like.
TRL – Technology Readiness level
ULA – United Launch Alliance
Vomit Comet – an aircraft flying parabolic flight paths, giving periodic weightlessness.
VSS – Virgin (Galactic) Space ship.
V&V – verification and validation
Zombie-Sat – dead satellite, in orbit

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